The Saudi Journal for Dental Research (2015) 6, 41–47

King Saud University

The Saudi Journal for Dental Research

www.ksu.edu.sa
www.sciencedirect.com

ORIGINAL ARTICLE

Chromatic stability of light-activated resin and heat-cure acrylic resin submitted to accelerated aging

Safa'a A. Asal [a,b,*], **Maha M. Fahmy** [a,b], **Saeed M. Abdulla** [c]

[a] *Department of Prosthetic Dental Sciences, College of Dentistry, King Saud University, Saudi Arabia*
[b] *Department of Prosthetic Dental Sciences, College of Dentistry, Tanta University, Egypt*
[c] *Department of Prosthodontics, Faculty of Dentistry, Tanta University, Egypt*

Received 8 May 2014; revised 8 June 2014; accepted 8 June 2014
Available online 27 June 2014

KEYWORDS

Color stability;
Light-activated resin;
Heat-cure acrylic resin

Abstract *Statement of the problem:* Several denture base resins providing easier/or faster processing have recently been introduced. Even though these materials have improved physical properties, their color stability is also of vital interest.

Objective: The purpose of this study was to determine quantitatively the effect of different colorant solutions on the color stability of Eclipse (visible-light-activated resin) in comparison to Lucitone-199 (heat-cure acrylic resin).

Materials and methods: Twenty one specimens from two tested materials, Eclipse (visible-light-activated resin) and Lucitone-199 (heat-cure acrylic resin) were prepared and stored for 24 h at 37 °C in distilled water. In a dimmed atmosphere, seven specimens of each tested material were stored in different colorant solutions (strawberry, coffee, and tea). Using a computer-controlled spectrophotometer, color measurements among the specimens were done before and after 252, 504, and 1008 h of immersion in the colorant solutions. Data were statistically analyzed.

Results: Ranova test showed significant differences ($p < 0.05$) between the color change mean values for Eclipse and Lucitone-199 at 252, 504, and 1008 h of accelerated aging. While paired t-test showed no significant difference of means in the color changes between the measuring intervals of each colorant solution with Eclipse. Lucitone-199 showed significant differences especially with coffee and tea colorant solutions.

* Corresponding author at: Department of Prosthetic Dental Sciences, College of Dentistry, King Saud University, Saudi Arabia. Tel.: +966 0509622169.
E-mail addresses: std2mster@gmail.com, std2m@yahoo.com (S.A. Asal).

Peer review under responsibility of King Saud University.

ELSEVIER Production and hosting by Elsevier

http://dx.doi.org/10.1016/j.sjdr.2014.06.003

Conclusions: Eclipse denture base material is significantly more color stable than the Lucitone-199. Tea has the highest discoloration effect on Eclipse, but within the acceptable clinical levels. On the other hand, coffee has more discoloration effect on Lucitone-199, while, the least staining effect was caused by strawberry colorant solution on both Eclipse and Lucitone-199.

1. Introduction

Despite the fact that most complete dentures are manufactured from heat-cure acrylic resin (PMMA), it seems that it is not the ultimate denture base material in some aspects. Several denture base resins that provide easier and faster processing have recently been introduced. The use of visible-light-polymerized urethane dimethacrylate (UDMA) was launched in the 1980s, and Triad was the initial light-polymerized denture base polymer attainable in the market.[1] Eclipse Prosthetic Resin System (UDMA) was the most recent addition of denture base polymer, where three types of resins (baseplate, setup and contour resins) are supplied for the construction of the denture.[2,3] Studies showed that Eclipse exhibits dramatically higher surface hardness, flexural strength, and flexural modulus, transverse strength, and shear bond strength of IPN denture teeth to denture base resins than PMMA denture base polymers.[2,4] Despite these materials having improved physical properties, their color stability is also of special importance. Esthetic outcome is a problem that can be encountered from discoloration of acrylic resin.

Smooth translucent surface with good esthetics matching the natural soft tissue appearance is an exclusive property of an ideal denture base polymer. The serviceability of these materials is dramatically affected by the color stability standards.[5] As the majority of these materials utilized for construction of dental prosthesis are subjected to sorption; a process of absorption and adsorption of liquids relies on environmental conditions. If the contacting solution is colored, discoloration is likely to occur.[6,7] Many studies have been reported on discoloration features of resin-based dental prosthodontic materials during exposure to oral fluids, and denture cleaners.[8–15] There is proof that colored drinks such as tea, coffee, and soft drinks dramatically augment the development of enamel and acrylic resin discoloration as well.[16] Accelerated aging is a test that uses aggravated conditions to expedite the normal aging procedures of the tested materials, to help determine the long-standing outcome at anticipated levels of stress within a shorter time. It is utilized usually in a laboratory by controlled standard test methods.

To quantify the color changes of dental materials, comprehension of color science and differential colorimetry is needed. Current photometric and colorimetric instruments are reliable to measure the color of acrylic resin specimens[5,15], and to demonstrate it in terms of three coordinate values (L^*, a^*, b^*), that situate the object's color within the CIELAB color space.[17] The L^* match symbolizes the color intensity of an object, the a^* value corresponds to the red or green chroma, and the b^* value represents the yellow or blue chroma. Numeric description of color allows precise definition of the magnitude of the color difference between objects. The equation utilized for calculating color differences in this system is[17,18]

$$\Delta E = \left[(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2\right]^{1/2}$$

where ΔE is the color difference of the two objects that can be determined by comparing the differences between individual values for each object.

Varied adequacy and perceptibility values for color variances in dental materials were reported by former researches.[19] The detection of color discrepancy depends on human perception of color. Formerly, studies reported that color differences greater than 1 ΔE unit are 50% visually detectable. Besides, under uncontrolled clinical conditions, such minor changes in color would be invisible, as average color differences below 3.7 are rated a "match" in clinical conditions.[20]

According to national and international standards, color stability of denture base resins is a required characteristic provide important information on the serviceability of the materials.[5,7] The purpose of this research was to quantitatively find out the effect of accelerated aging on the color stability of visible-light-polymerized urethane dimethacrylate (Eclipse) in comparison with heat-cure polymethyl methacrylate acrylic resin (Lucitone-199).

2. Materials and methods

Forty-two disk-shaped specimens of Eclipse and Lucitone-199 were equally divided into two groups. The specimens were prepared by utilizing a metal mold 15 mm in diameter and 2 mm in thickness (according to ADA specification no. 17) modified by the author with knock-out plate at the base Fig. 1(a and b).

Wax disks were formed by pouring molten inlay wax into the metal mold. After cooling, the excess wax, it was trimmed with a scalpel blade #11 to ensure a flat surface. The wax disks were removed from the metal mold by pushing the knock-out plate at the base of the mold. The Lucitone-199 specimens were prepared by investing the wax disks in dental stone using a denture flask Fig. 2. After wax elimination, Lucitone-199 acrylic resin specimens were constructed in a conventional manner according to manufacturer's recommendations. Eclipse specimens were prepared after retrieving the stone mold from the denture flask, application of a separating agent (Dentsply Int.), and conditioning the stone mold in a conditioning oven (Dentsply Int.) to 55 °C for 2 min. Using finger pressure, a section of 1 mm Eclipse baseplate resin was then applied into the mold. Air Barrier Coating (ABC) (Dentsply Int.) was applied and the specimens were cured in the Eclipse VLC processing unit for 10 min (Fig. 3). After bench cooling to room temperature and washing them out of the ABC coating, 1 mm of the Eclipse contour resin was applied onto the cured baseplate resin specimen. A new coat of ABC was applied, and the specimens were recurred.

All specimens were submitted to finishing for 1 min with Buehler abrasive disks no. 320, 400 (AKE, Illinois, USA),

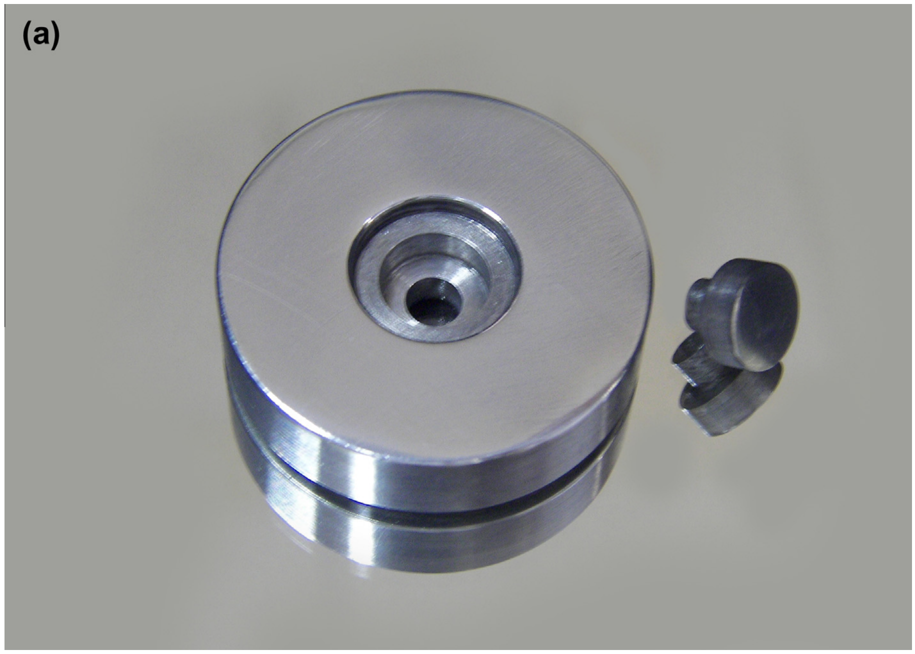

Figure 1a Metal mold modified with a knock-out plate.

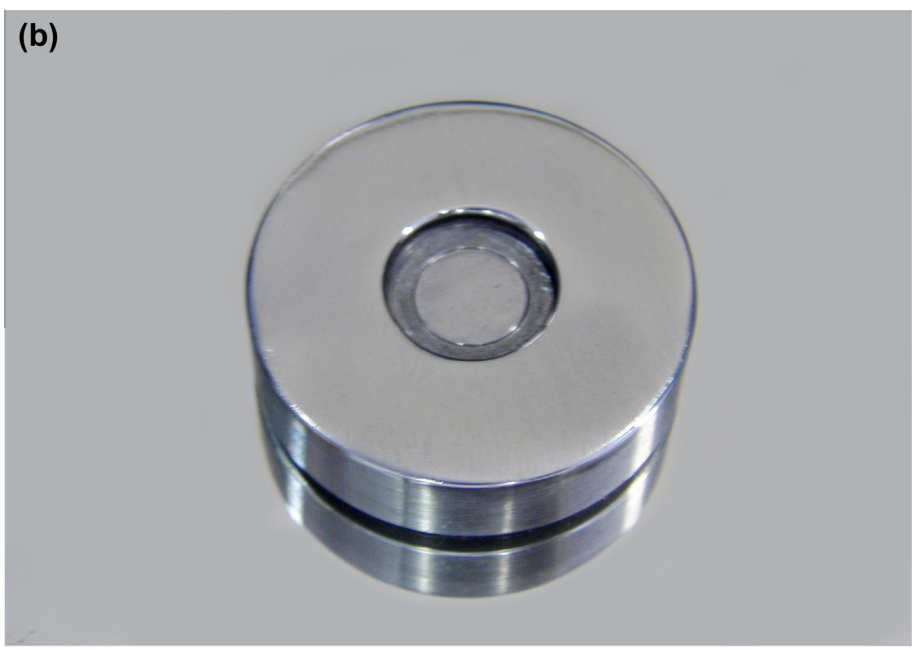

Figure 1b Assembled metal mold.

mechanical polishing with felt paper disk no. 600 using 0.3 and 0.05 polishing powder (Buehler micropolish© ∏, Rd. Lake Bluff, IL 60044, USA) in an automata grinding and polishing unit (Jeanwirtz Gmbh & Co. charlottrabe, Dusseldorf W, Germany) under water spray at minimal speed and then they were stored in water at 37 °C for 24 h.[21] Each group was numbered and divided into 3 subgroups (n = 7) according to the colorant solution into which the specimens were to be immersed. These colorant solutions were strawberry juice, coffee, and tea.

Reflectance spectrophotometer (color-Eye 7000A, Gretag Macbeth, NY, USA) was used to measure the color changes of the samples and calculate the diversity from the baseline color reading before and after 252, 504, and 1008 h of exposure to accelerated aging conditions.[22] Subsequent to the preliminary reading, the samples were placed in the colorant solution conditioning chamber at 37 °C in Imperial IV Laboratory oven (Lab-Line Inst. Inc., Melrose Park, IL, USA) to simulate the intraoral conditions. After 252, 504, and 1008 h of aging, the color measurements of all samples were repeated.

Figure 2 Investing wax disks using a processing flask.

Figure 3 Eclipse conditioning oven and VLC processing unit.

Color assessments were conducted in three randomly selected areas near the center of each resin sample. The average of the three readings was recorded and the mean color change of each material was calculated using the CIE Lab uniform color scale.

The level of the total color difference is formulated by a single number ΔE

$$\Delta E = \left[(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2 \right]^{1/2}$$

where L^* stands for lightness, a^* for redness-greenness, and b^* for yellowness–blueness.

A statistical analysis of color changes was performed. The magnitudes of the color changes displayed by the Eclipse and Lucitone-199 in the three colorant solutions were compared

Table 1 Comparison between the mean color changes of Eclipse and Lucitone-199 at the follow-up periods with strawberry colorant solution.

New		Eclipse	Heat-cure	t-Test	
		Mean ± SD	Mean ± SD	T	p-value
T_1		2.365 ± 0.652	4.454 ± 0.921	−4.636	0.001*
T_2		2.4 42 ± 0.596	5.065 ± 0.752	−6.883	0.000*
T_3		2.439 ± 0.435	6.984 ± 0.632	14.820	0.000*
RANOVA	F	1.115	5.511		
	P-value	0.351	0.0112		

T_1: ΔE after 252 h.
T_2: ΔE after 504 h.
T_3: ΔE after 1008 h.
* $p < 0.05$.

Table 2 Comparison between the mean color changes of Eclipse and Lucitone-199 at the follow-up periods with coffee colorant solution.

New		Eclipse	Heat-cure	t-Test	
		Mean ± SD	Mean ± SD	T	p-value
T_1		2.48 ± 0.476	4.738 ± 0.829	5.871	0.000*
T_2		2.619 ± 1.211	5.754 ± 0.549	6.178	0.000*
T_3		2.628 ± 0.632	7.784 ± 0.467	16.906	0.000*
RANOVA	F	1.08	6.18		
	P-value	0.401	0.004*		

* $p < 0.05$.

Table 3 Comparison between the mean color changes of Eclipse and Lucitone-199 at the follow-up periods with tea colorant solution.

New		Eclipse	Heat-cure	t-Test	
		Mean ± SD	Mean ± SD	T	p-value
T_1		2.92 ± 0.619	4.665 ± 0.693	4.749	0.0006*
T_2		3.129 ± 0.764	5.396 ± 0.840	−5.055	0.000*
T_3		3.541 ± 0.514	7.487 ± 0.543	13.382	0.000*
RANOVA	F	2.118	5.055		
	P-value	0.072*	0.028		

* $p < 0.05$.

Table 4 National Bureau of Standards (NBS) system of expressing color difference.

Critical remarks of color difference	ΔE NBS units
Trace	0.0–0.5
Slight	0.5–1.5
Noticeable	1.5–3.0
Appreciable	3.0–6.0
Much	6.0–12.0
Very much	12.0+

for an equivalent amount of time with the Paired t-test. Ranova test (Anova repeated measures) was used to analyze and compare the significance of color changes displayed by each specimen at different lengths of time in the same solution.

3. Results

Tables 1–3 show significant differences ($p < 0.05$) between the color change's mean (ΔE) values for Eclipse and Lucitone-199 at 252, 504, and 1008 h (T_1, T_2, and T_3, respectively) of accelerated aging using Ranova test (Fig. 3).

Derived from the National Bureau of standards system for conveying color difference (Table 4), the color changes for Eclipse were in the noticeable category with both strawberry, and coffee, and after 252 h in tea colorant solution, while with tea colorant solution the color change became noticeable at 504, and 1008 h which is clinically acceptable. On the other hand, the color changes for Lucitone-199 were in the category of significant after 252 and 504 h with the accelerating agents, but after 1008 h the color difference became significant, which is clinically unacceptable.

Paired t-test showed no significant difference of mean color changes between the measuring intervals of each colorant solu-

Table 5 Mean and SD of the color changes of Eclipse at follow-up periods.

Eclipse	T_1	T_2	T_3	Paired t-test		
	Mean ± SD	Mean ± SD	Mean ± SD	T_1–T_2	T_1–T_3	T_2–T_3
Strawberry	2.365 ± 0.652	2.442 ± 0.596	2.439 ± 0.435	0.511	0.602	0.88
Coffee	2.48 ± 0.476	2.619 ± 1.211	2.628 ± 0.632	0.452	0.581	0.902
Tea	2.92 ± 0.619	3.129 ± 0.764	3.541 ± 0.514	0.187	0.109	0.772

Table 6 Mean and SD of the color changes of Leucitone-199 at different follow-up periods.

Heat-cure	T_1	T_2	T_3	Paired t-test		
	Mean ± SD	Mean ± SD	Mean ± SD	T_1–T_2	T_1–T_3	T_2–T_3
Strawberry	4.454 ± 0.921	5.065 ± 0.752	6.984 ± 0.632	0.044	0.001*	0.018
Coffee	4.738 ± 0.829	5.754 ± 0.549	7.784 ± 0.467	0.028	0.001*	0.001*
Tea	4.665 ± 0.693	5.396 ± 0.840	7.487 ± 0.543	0.031	0.001*	0.001*

* $p < 0.05$.

tion with Eclipse, but Lucitone-199 showed significant difference especially with coffee and tea (Tables 5 and 6).

4. Discussion

Color changes can be evaluated visually or digitally. Colorimetric measurements allow a digital, quantitative, and reproducible means of color evaluation and eradicate the human interpretation of color variances. When changes in color occur below visual perception levels, spectrophotometric color measurements allow reproducible results. The CIE lab system is recommended by the Commission International de l'Eclairage (International Commission on Illumination).The benefit of this color system is that its arrangement is nearly uniform and three dimensional color space where its elements are equally spaced on the essence of visual color awareness.[23] A color graph consisting of independent variables in the form of L, a, and b coordinates can be attained by means of mathematical transformations. The sensitivity of the eye in observing color differences is limited. Color variances with corresponding ΔE lab values of 1.0 are perceptible,[23,24] while in dentistry ΔE lab values greater than 3.3 are unacceptable (Fig. 4).[19]

Different factors are responsible for the color changes of polymeric dental materials; some are intrinsic, while others are extrinsic factors.[25] Surface roughness, stains, water sorption as well as chemical degradation are other factors responsible for color unpredictability.[26,27]

Um and Ruyter[19] reported approximately twice as much discoloration in tea as in coffee for resin based veneering materials. In the present study, the discoloration values of the Lucitone-199 denture base material (ΔE) with coffee and tea were significant following different time intervals; however, with Eclipse no significant color changes were detected. This could be explained by the fact that each of the resins used in this study have incorporated miniscule amounts of various cross-linking agents, plasticizers and pigments, which may be the reason for difference in staining behavior of resins. Slight discoloration of acrylic resins may be as a result of some molecular interactions between the denture polymers and

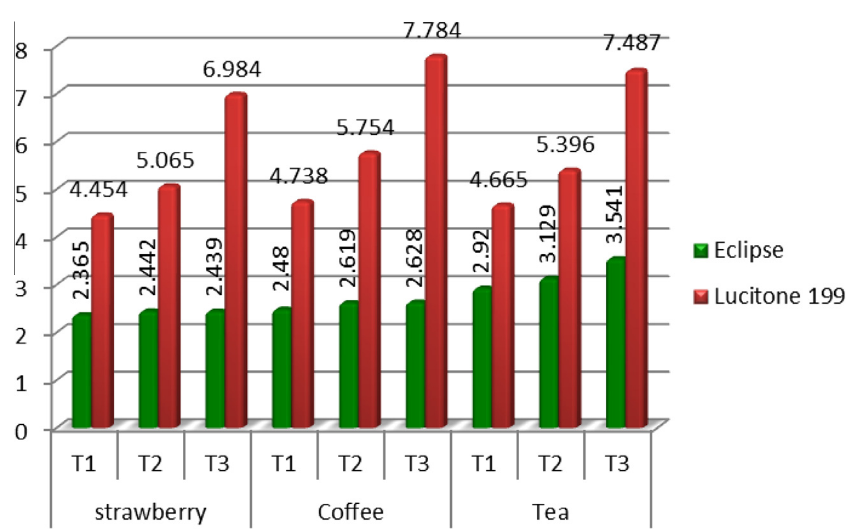

Figure 4 Materials' mean color change (ΔE) values at 252, 504, and 1008 h of accelerated aging.

the colorant solutions. This finding was in agreement with Imirzalioglu et al.[28]

Goldstein and Schmitt[29] reported that when ΔE is more than 3.7, it is clinically unacceptable. In our study, Lucitone-199, illustrated a greater staining in strawberry, coffee and tea colorant solutions (ΔE = 2.33, 3.04 and 2.82, respectively). After 1008 h, the color changes displayed by all specimens were at clinically acceptable levels. This superfluous discoloration detected with Lucitone-199 may be correlated to the rubber phase in its structure,[30] or to absorption of colorant solutions. The results of the present study validated that after 1008 h of immersion in strawberry, coffee and tea colorant solutions, coffee produced a higher discoloration value ΔE on the Lucitone-199. This finding was in agreement with Buyukyilmaz and Ruyter.[31]

Al-Mulla et al.[32] noticed no significant difference of Eclipse ΔE value between 100 and 300, this was in agreement with the results of this study proving that even with longer time period of up to 1008 h the color was still stable.

5. Conclusions

Within the limitations of this study, the following conclusions could be derived:

(1) Eclipse denture base resin is more color stable than the Lucitone-199.
(2) Tea causes more discoloration with Eclipse, while with Lucitone-199 coffee causes more discoloration.
(3) The least staining was caused by strawberry colorant solution with both Eclipse and Lucitone-199.

Conflict of interest

The authors declare no conflict of interest.

References

1. Graig RC. *Restorative dental materials*. 8th ed. St. Louis's Mosby; 1989, p. 509–59.
2. Machado C, Sanchez E, Azer SS, et al. Comparative study of the transverse strength of three denture base materials. *J Dent* 2007;**35**:930–3.
3. Grossmann Y, Savion I. The use of a light-polymerized resin-based obturator for the treatment of the maxillofacial patient. *J Prosthet Dent* 2005;**94**:289–92.
4. Ali IL, Yunus N, Abu-Hassan M. Hardness, flexural strength, and flexural modulus comparisons of three different cured denture base systems. *J Prosthodont* 2008;**17**:545–9.
5. Shotwell JL, Razzoog ME, Koran A. Color stability of long-term soft denture liners. *J Prosthet Dent* 1992;**68**(5):836–8.
6. Crispin BJ, Caputo AA. Color stability of temporary restorative materials. *J Prosthet Dent* 1979;**42**:27–33.
7. Phillips RW. *Science of dental materials*. 9th ed. Philadelphia: WB Saunders; 1991, p. 172–4.
8. Asmussen E. Factors affecting the color stability of restorative resins. *Acta Odontol Scand* 1983;**41**(1):11–8.
9. Raptis CN, Powers JM, Fan PL, Yu R. Staining of composite resins by cigarette smoke. *J Oral Rehabil* 1982;**9**:367–71.
10. Hayashi H, Maejima K, Kezuka K, Ogushi K, Kono A, Fusayama T. In vitro study of discoloration of composite resins. *J Prosthet Dent* 1974;**32**:66–9.
11. Cook WD, Chong MP. Color stability and visual perception of dimethacrylate based dental composite resins. *Biomaterials* 1985;**6**:257–64.
12. Moser JB, Wozniak WT, Muller TP, Moore BK. Use of the Munsell system to compute color differences in composite resins. *J Dent Res* 1978;**57**:958–63.
13. Wozniak WL, Muller TP, Silverman R, Moser JB. Photographic assessment of colour changes in cold and heat-cured resins. *J Oral Rehabil* 1981;**8**:333–9.
14. Nordbo H, Attramadal A, Eriksen HM. Iron discoloration of acrylic resin exposed to chlorhexidine or tannic acid: a model study. *J Prosthet Dent* 1983;**49**:126–9.
15. Khan Z, von Fraunhofer JA, Razavi R. The staining characteristics, transverse strength, and microhardness of a visible light-cured denture base material. *J Prosthet Dent* 1987;**57**:384–6.
16. Ertaş E, Güler AU, Yücel AC, Köprülü H, Güler E. Color stability of resin composites after immersion in different drinks. *Dent Mater J* 2006;**25**(2):371–6.
17. May KB, Razzoog ME, Koran III A, et al. Denture base resins: comparison study of color stability. *J Prosthet Dent* 1992;**68**: 78–82.
18. Berns RS, Bilmeyer FW, Saltzman M. *Principles of color technology*. 3rd ed. New York: Wiley; 2000, p. 71–4.
19. Um CM, Ruyter IE. Staining of resin-based veneering materials with coffee and tea. *Quintessence Int* 1991;**22**:377–86.
20. Recommendations Uniform Color Spaces. Color difference equations, psychometric color terms, CIE Publication No. 15, Suppl No. 2. Paris: Bureau Central CIE; 1968. p. 9–12.
21. Balderamos LP, O'Keefe KL, Powers JM. Color accuracy of resin cements and try-in pastes. *Int J Prosthodont* 1997;**10**:111–5.
22. Goiato MC, Santos DM, Souza JF, Moreno A, Pesqueira AA. Chromatic stability of acrylic resins of artificial eyes submitted to accelerated aging and polishing. *J Appl Oral Sci* 2010;**18**(6):641–5.
23. Kuehni RG, Marcus RT. An experiment in visual scaling of small color differences. *Color* 1979;**4**:83–91.
24. Knispel G. Factors affecting the process of color matching restorative materials to natural teeth. *Quintessence Int* 1991;**22**: 525–31.
25. Villalta P, Lu H, Okte Z, Garcia-Godoy F, Powers JM. Effects of staining and bleaching on color change of dental composite resins. *J Prosthet Dent* 2006;**95**:137–42.
26. Anil N, Hekimoglu C, Sahin S. Color stability of heat-polymerized and auto-polymerized soft denture liners. *J Prosthet Dent* 1999; **81**:481–4.
27. Kiat-Amnuay S, Mekayarajjananonth K, Powers JM, Chambers JC, Lemon JC. Interactions of pigments and opacifiers on color stability of MDX4-4210/TYPE A maxillofacial elastomers subjected to artificial accelerated aging. *J Prosthet Dent* 2006;**95**: 249–57.
28. Imirzalioglu P, Karacaer O, Yilmaz B, Ozmen I. Color stability of denture acrylic resins and a soft lining material against tea, coffee, and nicotine. *J Prosthodont* 2010;**19**(2):118–24.
29. Goldstein GR, Schmitt GW. Repeatability of a specially designed intraoral colorimeter. *J Prosthet Dent* 1993;**69**:616–9.
30. Stafford GD, Bates JF, Haggett R, Handley RW. A review of the properties of some denture base polymers. *J Dent* 1980;**8**:292–306.
31. Buyukyilmaz S, Ruyter IE. Color stability of denture base polymers. *Int J Prosthodont* 1994;**7**:372–8.
32. Al-Mulla MAS, Huggett R, Brooks SC, Murphy WM. Some physical and mechanical properties of a visible light-activated material. *Dent Matr* 1988;**4**:197–200.